The effect of pressure on the critical temperature of a superconducting transition of the $Fe_x SnMo_6S_8$ system

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The effect of pressure on the critical temperature of the $Fe_x SnMo_6S_8$ system is analyzed. The introduction of iron ($x = 0.04$) into the system increases the value of $|dT_c/dP|$ by a factor of approximately three.

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Alekseevskiĭ *et al.* have reported elsewhere[1] that the critical temperature T_c of a superconducting transition of ternary molybdenum sulfides (TMS) decreases sharply upon the introduction of a small amount of iron impurity. The quantity dT_c/dc for $Fe_xSnMo_6S_8$ amounts to 26 K/at.%, where c is the impurity concentration. It was shown that the T_c of TMS decreases precipitously with the concentration as the electronic specific heat increases.[1] Alekseevskiĭ *et al.*[2] and Shelton *et al.*[3] have shown, on the other hand, that TMS have large negative values of the derivative of T_c with respect to pressure. It can be assumed that the effect of pressure on the critical temperature increases with increasing concentration of the magnetic impurity.

To verify this assumption, we have investigated the effect of pressure on the critical temperature of the $Fe_xSnMo_6S_8$ system for $x=0$, 0.02, and 0.04. The samples were synthesized directly from the elements. The iron content was controlled by means of an activation analysis.[1)] With a nominal Fe content in the samples, $x=0$, 0.02, and 0.04, corresponding to 0, 0.133, and 0.266 at.%, an analysis of Fe content yielded the values 5.3×10^{-3}, 0.11, and 0.25 at.%. The pressure was produced in a constant-pressure vessel similar to the one described in Ref. 4. The temperature was measured with a Cu-Cu $Fe_{0.01\%}$ thermocouple which was introduced into the high-pressure region. The transition to the superconducting state was recorded by using an inductive method. To avoid ambiguity in the measurements, we measured the critical temperature of all three samples in a single experiment by inserting them into the high-pressure vessel at the same time.

The critical temperature T_c is plotted in Fig. 1 as a function of pressure for the samples with different iron contents. We see from the given data that T_c falls off sharply under pressure after a small amount of iron ($c<0.3$ at.%) is introduced into the sample. The quantity dT_c/dP for the samples with $x=0$, 0.02, and 0.04 corresponds to -1.2×10^{-4}, and -3.4×10^{-4} K $\cdot$ bar^{-1}, respectively, i.e., it increases in absolute value by a factor of approximately three. The value $|dT_c/dP|=3.4\times 10^{-4}$ K $\cdot$ bar^{-1} is approximately a factor of two larger than the maximum values of $|dT_c/TP|$ for TMS (Ref. 3) and therefore is a record value. The value of $|dT_c/dP|$ for superconductors generally is equal to $\sim 10^{-5}$ $K\cdot$ bar^{-1}.

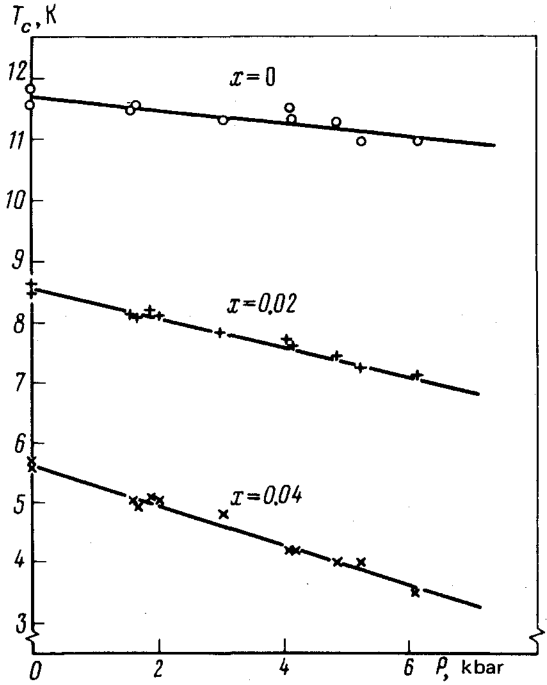

FIG. 1. Dependence of the critical temperature of the superconducting transition on the pressure for three samples of the system $Fe_xSnMo_6S_8$.

If the compressibility is known, we can determine the T_c shift with the volume. The value of $d\ln T_c/d\ln V$ can be estimated if we assume that $\kappa = 2.8 \times 10^{-6}$ bar^{-1} is the upper limit of the compressibility κ (Ref. 5) and that this value changes slightly after the introduction of a small amount of iron. For $x=0$ the derivative $d\ln T_c/d\ln V$ is equal to 3.6 and for $x=0.04$ it increases by a factor of approximately six and reaches a value of 21. The presence of a localized magnetic moment in Fe impurity atoms can be inferred from the large values of dT_c/dc,[1] from the strong temperature dependence of the magnetic susceptibility and from the minimum on the plot of the electrical resistance vs. temperature.[6]

It was reported elsewhere[1] that the large values of the effective moment $\mu_{\rm eff}$ in iron atoms, obtained from the measurement of the magnetic susceptibility, may be the consequence of an indirect exchange and that they account for the possible ferromagnetic instability of these systems similar to that discussed in Ref. 7.

If we use our data in a plot of the critical temperature T_c as a function of impurity concentration at different pressures, we find that the value of $|dT/dc|$ increases by 30% at a pressure of 6 kbar, i.e., it increases from 23 K/at.% to 29 K/at.%.[2)]

This result may be regarded as an intensification of the pressure-induced interaction of conduction electrons with the localized magnetic moments of impurity atoms.

[1]We wish to thank V. N. Samosyuk for performing the analysis.
[2]If we would use the Abrikosov and Gor'kov theory,[8] then this would correspond to an increase of the exchange-interaction constant from 0.26 to 0.29.

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